Generation Interconnection Feasibility Study

for

Western Area Power Administration Upper Great Plains Region GI-0814 – 201 MW

CEII Removed - Critical Energy Infrastructure Information

Version 1.2

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TranServ Project 223

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Executive Summary

Western Area Power Administration (Western, a.k.a. WAPA) commissioned TranServ to perform an Interconnection Feasibility Study (IFS) for a 201 MW wind farm Large Generator Interconnect (LGI) to the Western/Heartland Consumers Power District/Basin Electric Power Cooperative Integrated System (IS) on Western's Havre-Rudyard-Shelby2 115 kV Transmission Line near West Joplin, Montana. This request is identified as Request No GI-0814 on Western's Generation Interconnection Queue posted on its Open Access Same-Time Information System (OASIS).

This is a joint feasibility study report by WAPA and TranServ. The feasibility study was performed by TranServ under WAPA direction. The feasibility study report was compiled by WAPA based on the study results provided by TranServ. WAPA also made determination of injection constraints that are required to be mitigated by the Interconnection Customer and developed the mitigation plan for interconnection with consultation from the Ad Hoc Study Groups

This IFS evaluated the impact of the proposed wind farm on transmission system performance, including steady-state and short-circuit analysis. The scope of the IFS is limited to identifying mitigation for injection constraints that likely would limit the ability of the generator to interconnect. In accordance with WAPA IFS practices, this study only identifies injection related steady-state impacts (i.e. local area thermal and voltage impacts under system intact and N-1 contingency conditions) and short-circuit impacts that would be required to be mitigated in order for this LGI to interconnect at the requested Point of Interconnection (POI).

Due to sparse commercial and residential load within WAPA's WAUW control area, interconnection of GI-0814 as a Network Resource (NR) to serve native load is not feasible. Available load within the WAUW control area to sink GI-0814 is significantly inadequate. The impacted study area is roughly defined as North Central Montana, which includes the bulk electric system (BES) from the Corp of Engineers Fort Peck Plant at the East boundary, Rocky Mountains at the west boundary, Canada to the North and NorthWestern Energy's (NWE's) Great Falls, MT transmission hub to the South. The study area is also commonly referred to as the North of Great Falls area (NOGF). The study area transcends both the WAPA-WAUW and NWE-NWMT control areas. The BES within the study area includes WAPA, NWE and Rural Utility System (RUS) transmission facilities. Since the study area and WAUW control area are both electrically isolated to the East, West and North, all bulk generation in excess of local native load must be dispatched South of Great Falls over NWE's transmission system and the NWMT control area. NWE's South of Great Falls (SOGF) interface has been previously identified in numerous studies as a congested path. Therefore, this IFS focuses on interconnection as an Energy Resource (ER) with and without system upgrades. GI-0814 generation is dispatched South of Great Falls over NWE's transmission system to the USBR Grand Coulee Power Plant located in central Washington, within the Northwest Power Pool (NWPP) service territory.

Any results related to the delivery of power from this project are for informational purposes only, including the BES beyond the study area, i.e. South of Great Falls. Such results are beyond the required scope of this IFS. A separate delivery study would be required to identify delivery related impacts and associated system upgrades, if required.

This IFS included all combined 'active' prior queue projects that resulted from ad-hoc input by the BES Transmission Operators (TOs) and RUS Cooperatives within and interconnecting the study area. Based on 'active' prior queue projects within the WAUW and NWMT control areas, the following interconnect options with conceptual costing were determined for GI-0814:

1) Interconnection of 70 MW of Energy Resource (ER) is feasible with minimal facility improvements. This conceptual cost option is $2.9M.[1]

2) Interconnection of 201 MW of (ER) is feasible with complete 230kV conversion of WAPA's Shelby2-Havre 115kV system and Havre-Verona-Great Falls 161kV system. This conceptual cost option is $77.3M.[2]

3) Interconnection of 201 MW of (ER) is feasible with installation of a WECC/NERC approved Remedial Action Scheme (RAS) that will immediately reduce generation for localized contingencies and emergency conditions in lieu of a complete 230 kV conversion as stated in Option 2). Conversion of WAPA's 115 kV system from the POI to Shelby 2 would still be necessary. This conceptual cost option is $25.1M.[3]

Both options 1) and 2) may still require a RAS for stability, operational and delivery issues evidenced by delivery studies (i,e, System Impact Study and Transmission Service Request Study). G-0814's impact on the BES as identified in this report may become invalid if the assumptions made about 'active' prior queued generation projects prove to be incorrect.

[1] Planning level non-binding conceptual cost estimate. See Section 6 for estimate details.
[2] Planning level non-binding conceptual cost estimate. See Section 6 for estimate details.
[3] Planning level non-binding conceptual cost estimate. See Section 6 for estimate details.

Steady-State Analysis:

The interconnection of the proposed GI-0814 wind farm at 201 MW impacted several transmission facilities and resulted in steady-state criteria violations. Worst case steady-state analysis was based on extreme light loading with heavy export transfer of both existing and prior queue generation in the study area. The Corp of Engineers Fort Peck plant generation was modeled at 90 MW, Glacier Wind 1 plant at 104 MW and Glacier Wind 2 plant at 100 MW. Prior studies clearly indicate that a heavy loading scenario is a least extreme scenario due to the lightly loaded, generation rich study area North of Great Falls. Therefore, a heavy loading scenario was not analyzed and a more detailed analysis was performed on a near-term 2010 Light Autumn case. This case was conditioned for extreme light loading as recently recorded by both WAPA and NWE historical data. The study area has historically experienced load growth less than 1% per year.

- Pre-Contingent overloads and voltage violations that could not be mitigated for 201 MW output were observed with interconnection to WAPA's existing 115 kV system. Previous System Impact Studies (SIS) have reveiled stability related issues in the study area that relate to the proximity of the Fort Peck hydro generation plant.
- Pre-Contingent and N-1 Post-Contingent overloads and voltage violations NOGF are mitigated with interconnection to WAPA's existing 115 kV system by reducing output to 70 MW. This output level is constrained by Post-Contingent thermal overload of NWE's 60 MVA 161/100 kV Rainbow transformer. Additionally some Post-Contingent voltage violations are observed South of Great Falls on NWE's 100 kV system, with post-project voltage impacts of 2.1% or less (provided as information only).
- Pre-Contingent and N-1 Post-Contingent overloads and voltage violations North of Great Falls are mitigated with interconnection at 230 kV operation to WAPA's system.
- Interconnection at 230 kV requires a minimal conversion of the existing 115 kV system from the POI to the WAPA Shelby 2 terminal. This minimal conversion would require a remedial action scheme (RAS) to curtail generation for specified N-1 contingencies.
- Interconnection at 230 kV without a RAS requires 230 kV conversion of WAPA's Shelby 2-Havre 115kV system and Havre-Verona-Great Falls 161 kV system. Additionally some Post-Contingent thermal overload and voltage violations are observed South of

Great Falls on NWE's 230 kV and 100 kV systems, with post-project thermal impacts of 45.6 % or less and voltage impacts of 6.5% or less (provided as information only).

Stability Analysis:

Dynamic stability analysis is outside the scope of this study.

Constrained Interface / Flow Gate Analysis:

There are no constrained interfaces and/or flow gates defined within the study area. Therefore, no constrained interface analysis was performed with dispatch of Project GI-0814 South of Great Falls over NWE's transmission system to the USBR Grand Coulee Power Plant located in Central Washington.

Short Circuit Analysis:

Short circuit analysis of available fault currents were performed for the immediate project area, specifically Western's Havre-Rudyard-Shelby2 115 kV system and the RUS Cooperative's associated underlying 69 kV system. A comparison of the fault currents to breaker capabilities at the associated facilities indicates adequate interrupting capabilities for the 70 MW 115 kV option. No short circuit analysis was performed for 230 kV interconnection since new equipment is required for conversion to 230 kV operation.

1. Introduction

Western Area Power Administration (Western, a.k.a. WAPA) commissioned TranServ to perform an Interconnection Feasibility Study (IFS) for a 201 MW wind farm Large Generator Interconnect (LGI) to the Western/Heartland Consumers Power District/Basin Electric Power Cooperative Integrated System (IS) on Western's Havre-Rudyard-Shelby2 115 kV Transmission Line near West Joplin, Montana. This request is identified as Request No GI-0814 on Western's Generation Interconnection Queue posted on its Open Access Same-Time Information System (OASIS).

This IFS evaluates the capability of the existing Havre-Rudyard-Shelby2 115 kV line and local transmission system to accommodate the 201 MW LGI as both a Network Resource (NR) and an Energy Resource (ER). Following preliminary analysis of interconnection at 115kV, two alternatives were evaluated; 1) an alternate output of 70 MW wind at 115 KV interconnection was determined to be the maximum output the project could transfer with the existing 115 kV bulk electric system (BES), and 2) interconnection at 230 kV for unconstrained transfers of 201 MW out of the study area, which includes conversion of both of WAPA's Havre-Rudyard-Shelby2 115 kV line and Havre-Verona-Great Falls 161 kV line to 230 kV operation.

Due to sparse commercial and residential load within WAPA's WAUW control area, interconnection of GI-0814 as a Network Resource (NR) to serve native load is not feasible. Available load within the WAUW control area to sink GI-0814 is significantly inadequate. The impacted study area is roughly defined as North-Central Montana, which includes the bulk electric system (BES) from the Corp of Engineers Fort Peck Plant at the East boundary, Rocky Mountains at the west boundary, Canada to the North and NorthWestern Energy's (NWE's) Great Falls, MT transmission hub to the South. The study area transcends both the WAPA WAUW and NWE NWMT control areas. The BES within the study area includes WAPA, NWE and Rural Utility System (RUS) transmission facilities. Since the study area and WAUW control area are both electrically isolated to the East, West and North, all bulk generation in excess of local native load must be dispatched South of Great Falls over NWE's transmission system and the NWMT control area. NWE's South of Great Falls interface has been previously identified in numerous studies as a congested path. Therefore, this IFS focuses on interconnection as an Energy Resource (ER) with and without system upgrades. GI-0814 generation is dispatched South of Great Falls over NWE's transmission system to the USBR Grand Coulee Power Plant located in central Washington, within the Northwest Power Pool (NWPP) service territory.

This study considered the GI-0814 project's steady-state and pre- post-contingent impact on transmission system facilities for system intact and N-1 contingent outage conditions within the study area. Additionally, limited short circuit analyses was conducted within the study area, but the study does not include analysis of the constrained interfaces or dynamic stability analysis.

2. Description of Request

Project GI-0814, to be located in North-Central Montana, is a new wind farm requesting a point of interconnection (POI) to the existing Havre-Rudyard-Shelby2 115 kV line approximately midway between the Rudyard Substation and Tiber Tap location, near West Joplin, MT. To accommodate this request, a new 34.5/115 kV collector substation and 15 mile 115 kV transmission line would be constructed to the POI. Figure 2-1 shows the impacted study area of North-Central Montana and the project POI location.

Figure 2-1: GI-0814 Project Location & Study Area (CEII)

Project GI-0814 is assumed to consist of one hundred and thirty four GE 1.5 MW wind turbine generators at 201 MW total output and injection into the BES. The wind farm was modeled as one equivalent generator rated at 201 MW with reactive power capability of + 95% and – 95% power factor (+66 MVAR and -66 MVAR) and a scheduled voltage of 1.02 p.u. at the POI. The equivalent generator was connected to a 575V/34.5 kV equivalent generator step-up transformer. The equivalent generator step-up transformer is directly connected to two 105 MVA 34.5/115 kV transformers at the collector site. The 70 MW 115 kV option was modeled similar to the 201 MW 115kV option, however, the machine VAR capability were reduced (+23 MVAR and -23 MVAR) and a single 105 MVA 34.5/115 kV transformer assumed. Figure 2-1 illustrates this model option.

The 201 MW 230 kV option was modeled similarly to the 201 MW 115 kV option at the collector site, with 15 miles of 230 kV transmission from the collector site to the POI. BES conversion to 230 kV for this option included the existing Havre-Rudyard-Shelby2 115kV line, Havre-Verona-Great Falls 161 kV line, and associated station facilities. Western is presently re-constructing the existing Havre-Verona-Great Falls 161 kV line to 230 kV specification for future energization at 230 kV. This re-construction project is scheduled for completion 2016. However, it will continue to be operated indefinitely at 161 kV. Figure 2-1 illustrates this model option.

WAPA's minimum requirement for generation VAR control is +/- 0.95 power factor at the POI. However, due to voltage sensitivity of the project area, this project would be required to maintain a voltage schedule of 1.02 p.u. at the POI and is therefore modeled accordingly. This study does not identify or model 34.5 kV collector bus reactive compensation which may be needed to off-set the reactive power losses from the generator terminals for various wind generation output levels. A System Impact Study (SIS) may show a need for such compensation.

This study assumes completion of WAPA's new 230 kV interconnection at NWE's Great Falls Substation, scheduled to be in-service 2010. This new interconnection replaces WAPA's existing 100 kV interconnection at the NWE Rainbow Substation. WAPA's BES will continue to be operated at 161 kV and be transformed from 161 kV at the NWE point of interconnection.

Figure 2-2: GI-0814 Project Connection to Existing/Planned Facilities at 201 MW @ 115 Kv (CEII)

Figure 2-3: GI-0814 Project Connection to Existing/Planned Facilities at 201 MW @ 230 kV (CEII)

3. Study Criteria, Methodology, and Assumptions

3.3.1 Ad Hoc Study Group

This Interconnection Feasibility Study (IFS) for Project GI-0814 was performed by TranServ under the direct supervision of WAPA. An ad hoc study group was formed for study input from the following transmission owners (TOs) and local Rural Utility Service (RUS) Cooperatives that potentially could be affected by the Project's injection of generation to the BES:

- NorthWestern Energy, Butte, MT
- Glacier Electric Cooperative, Cut Bank, MT
- Hill County Electric Cooperative, Havre, MT
- Marias River Electric Cooperative, Shelby, MT

3.3.2 Computer Programs and Input Files

Siemens Power Technologies, Inc. (PTI) PSS/E and MUST computer power flow programs and evaluation software were used to determine system performance. Analysis was performed using MUST version 9.0 and PSS/E version 31.

3.3.3 Pre-project Model Development

Project GI-0814 was evaluated using a 2010 Light Autumn (LA) power flow case, PSSE version 31.0. This base case originated from a current WAPA operating study developed in concert with NWE. All pre-conditioning of the base case for the purpose of this study was provided by WAPA and NWE, which included verification and addition of all prior queue projects and associated mitigations.

Worst case steady-state analysis was based on extreme light loading with heavy export transfer of both existing and prior queue generation in the study area. Prior studies clearly indicate that a heavy loading scenario is least a extreme scenario due to the lightly loaded, generation rich study area. Therefore, a heavy loading scenario was not analyzed and a more detailed analysis was performed on a near-term 2010 Light Autumn case. This case was conditioned for extreme light loading as recently recorded by both WAPA and NWE historical data. The North Central Montana study area has historically experienced load growth less than 1% per year.

A. Summary of Project GI-0814 Parameters

Unit Type/Model	= GE 1.5 - 60 Hz, Double-fed Induction Turbine
Power Factor	= .95 Lead/Lag
Unit Rating	= 1.5 MW
Total No. of Units	= 134

Total Plant Capacity = 201 / 201 MW, Summer / Winter.
Collector Voltage = 34.5 kV
Collector System = 34.5 - 115 kV (230 kV alternate) Substation by Owner (Gnd Y / Delta / Gnd Y)
Delivery to POI = 15 miles 115 kV H-frame Transmission by Owner
Regulation = Voltage Control (scheduled to 1.02 p.u. at POI bus)

B. Summary of Existing Resources in Study Area and WAUW Control Area

Primary generation and system transfers associated with the study area were set as follows:

Fort Peck Plant	= 90 MW
Tiber Plant	= 7.5 MW
Canyon Ferry Plant	= 58 MW
Great Falls Plants	= 281 MW
Glacier Wind 1 Plant	= 104 MW
Glacier Wind 2 Plant	= 100 MW
Miles City DC Tie	= 200 MW East-West
Crossover Phase Shifter	= 77 MW North-South

All prior queue generation projects reside within the NWE-NWMT control area and interconnect to NWE as the transmission operator (TO). Table 3-1 illustrates the current listing of NWE's prior queued projects. These projects and associated mitigations, as specified by NWE, were included in the 2010 LA base case.

Table 3-1 Prior Queued Generation Interconnects

NWE Project Number	Date of Interconnection Request	Location	Point of Interconnection (POI)	In-Service Date Requested	Summer Output (MW)
32	July 1, 2004	Cascade County, Montana	Great Falls 230 kV Switchyard	October 31, 2008	268
33	November 3, 2004	Wheatland County, Montana	Martinsdale Substation	June 30, 2009	52.5
44 (GW1)	April 10, 2006	Pondera County, Montana	South Cut Bank to Conrad Auto 115 kV	October 15, 2008	104 MW
46	June 5, 2006	Meagher County, Montana	100 kV line between Loweth and Two Dot at Groveland.	September 1, 2007	10 MW
47	June 8, 2006	Liberty County, Montana	69 kV line at Chester	December 31, 2009	20 MW
49	June 16, 2006	Cascade County, Montana	Rainbow Switchyard	December 31, 2011	23 MW
53	December 6, 2006	Cascade County, Montana	Great Falls 230 kV Switchyard	July 1, 2007	277 MW
73 (GW2)	July 13, 2007	Glacier County, Montana	Cut Bank 115 kV Substation between Cut Bank & Shelby	November 30, 2008	100 MW
78 (GW1)	December 11, 2007	Glacier County, Montana	115kV between Cut Bank & Conrad	November 30, 2008	100 MW
81	March 11, 2008	Cascade County, Montana	Near Rainbow Switchyard	May, 2011	12 MW
82	March 11, 2008	Cascade County, Montana	Near Rainbow Switchyard	February, 2010	Efficiency Improvement
87 (GW2)	April 18, 2008	Glacier County, Montana	Cut Bank 115 kV Substation between Cut Bank & Shelby	November 30, 2008	100 MW
89	April 24, 2008	Meagher County, Montana	100 kV line between Loweth and Two Dot at Groveland.	July 31, 2009	20 MW

These projects may become a reality in part, all, or none, depending on the requestor's decision to-proceed or not-to-proceed through the Transmission Operator's (TO's) Open Access Same-Time Information System (OASIS).

3.3.4 Post-Project Model Development

Project GI-0814 generation was dispatched South of Great Falls (SOGF) and West over both the NWE and Bonneville Power Administration (BPA) transmission systems to the USBR Grand Coulee Power Plant located in central Washington state, as listed in Table 3-2 below. This dispatch was chosen in support of the extreme light loading with heavy export transfers out of Central and Western Montana. It should be noted that transfers East out of Montana into the

MAPP region and East Interconnected System are precluded by firm sold schedules across the Miles City DC Convertor Station.

Table 3-2
Project GI-0814 Generation Sink

Bus Name	Bus Number	70 MW Option	201 MW Option
Grand Coulee Dam	40296	-70	-201

The 2010 LA pre-project base case was modified to include the project's 201 MW 115 kV interconnection as requested. Initial steady state, system intact analysis with 201 MW interconnected to the 115 kV BES provided wide spread system voltage collapse of the study area and a post-project base case that would not converge. With the addition of 75 MVAR shunt capacitive support at the POI, a post-project base case that would converge was accomplished. However, system intact incremental losses for the Havre-Rudyard-Shelby2 115 kV line exceeded 18 MW and 49 MVAR. Total losses of the 15 mile 115 kV line from the collector site to the POI exceeded 12 MW and 33 MVAR. Total combined losses exceeded 30 MW and 82 MVAR. Optimal Surge Impedance Level (SIL) loading is approximately 40 MVA for a 115 kV line and 150 MVA for a 230 kV line. This post-project base case with interconnection at 115 kV also evidenced system intact thermal overloads that would require individual mitigation. Due to the extreme power flow stress to the BES and known stability issues in the study area, interconnection of 201 MW at 115 kV was not evaluated for N-1 contingencies or mitigation and was deemed not feasible.

The pre and post-project base cases utilized for this study are listed in Table 3-3 below.

Table 3-3
GI-0814 Pre and Post-Project Cases

Project GI-0814 Generation (MW)	Base Case Model Name
Pre-project	10la_gi0814_115kV.sav 10la_gi0814_230kV.sav
201	10la_gi0814_Trans_115kV.sav 10la_gi0814_Trans_230kV.sav
70	10la_gi0814_Trans_115kV@70MW.sav

3.3.5 Scope of Study Procedures

This study was performed in accordance with the WECC/NERC Reliability Criteria. To evaluate the impact of this project on the BES, the following analyses as described below was accomplished using the pre and post-project base cases described in Table 3-3 above.

- Single Contingency (N-1) Analysis. This analysis identified injection related constraints (i.e. requiring network upgrades) beyond the POI which result from single element outages as well as loss of multi-circuit towers, or other possible NERC Category C credible events (per NERC Transmission Planning Standard TPL-003).
- Short Circuit Analysis. This analysis identified fault current interrupting deficiencies of existing circuit breakers, specifically Western's Havre-Rudyard-Shelby2 115 kV system and the RUS Cooperative's associated underlying 69 kV system. No short circuit analysis was performed for 230 kV interconnection since new equipment is required for conversion to 230 kV operation.

Dynamic stability, prior outage and constrained interface analyses were not within the scope of this Interconnect Feasibility Study (IFS).

3.3.6 Contingency Analysis

Single Contingency (N-1) performance evaluation was performed via PSSE MUST AC solution techniques. A complete list of credible N-1 contingencies for both the WAPA and NWE control areas (WAUW and NWMT) were provided by WAPA as listed in Appendix E. The AC solutions were configured to allow operation and adjustment of switched shunts, transformer taps, DC taps, and phase shifters. Area interchange control was disabled.

Table 3-4 shows the monitored areas. Generator step-up transformers were not monitored.

Table 3-4
Model Areas Monitored

Balancing Authority	Area	Monitored Element	
		kV min	kV max
WAPA - WAUW	63	69	500
NWE - NWMT	62	69	500

3.3.7 WECC / NERC / WAPA System Performance Criteria

WAPA's performance criteria meets or exceeds WECC / NERC critieria.

Transmission system voltages were monitored against the following WECC / NERC reliability criteria:

1. System Intact Operation: min.=0.95 p.u. max.=1.05 p.u.
2. Post-Contingent Operation: min.=0.90 p.u. max.=1.10 p.u.

Western operates the BES to a nominal voltage schedule between 0.99 and 1.04 per unit (p.u.).

The WAUW system operating limits (SOL) were monitored against the following WAPA reliability criteria:

1. System Intact Operation: 100% of NORMAL for All Facilities (RATE A)

1. Emergency Operation: 100% of NORMAL for Conductor (RATE B)
   (i.e. Post-Contingent) 110% of NORMAL for Facilities (RATE B)
   125% of NORMAL for Transformers (RATE B)

Emergency SOLs are short-term loading limits that may not exceed 30 minutes. Within 30 minutes, reliability criteria dictates the system must be restored within Normal SOLs. Other WECC members may have different reliability limitations on emergency ratings and operation. For planning purposes, NWE's system operating limits (SOL) for Emergency operation do not exceed Normal operation levels (RATE A = RATE B).

3.3.8 Pre and Post Project Impact Screening

System Intact and Contingency analysis was performed to determine the impact of the project for system intact and post-contingent operation. This study monitors the WAUW control area (Area 63) and NWMT control area (Area 62). This analysis was performed and screened for impacts in accordance with the following WAPA generation interconnect and transmission service request criteria:

- Pre and Post Project: All branches loaded above their normal rating (Rate A) for system intact or their emergency rating post-contingent (Rate B), or between their normal and emergency ratings post-contingent.
- Post Project: All branches loaded with a Power Transfer Distribution Factor (PTDF) increase of greater than 5% MVA system intact, or Outage Distribution Factor (OTDF) greater than 3% MVA post-contingent, where:

$$\text{PTDF (\%)} = 100 \times \frac{\begin{array}{c}\text{System Intact}\\ \text{MVA flow (Post-Project)}\end{array} - \begin{array}{c}\text{System Intact}\\ \text{MVA flow (Pre-Project)}\end{array}}{\text{Project Injection or Transfer to BES}}$$

$$\text{OTDF (\%)} = 100 \times \frac{\begin{array}{c}\text{Post-Contingent}\\ \text{MVA flow (Post-Project)}\end{array} - \begin{array}{c}\text{Post-Contingent}\\ \text{MVA flow (Pre-Project)}\end{array}}{\text{Project Injection or Transfer to BES}}$$

Interconnection and transmission service customers of WAPA's BES must mitigate all the post-project system constraints (i.e. constrained interfaces, SOL branch overloads, and BES voltage degradation).

This study report identifies all system impacts and constraints within the study area in excess of the above listed DF (PTDF and OTDF) screening criteria. Included in the Appendices are system impact DFs beyond the study area, which are provided for information only. Those DFs may or may not imply delivery and/or transmission service related impacts. This IFS study only addresses interconnection.

4. Steady State Analysis Results

The summary of results provided in this section of the report identifies those results that are relevant to the NOGF study area. Provided in the Appendices of this report are complete results for both the WAUW and NWMT control areas, which includes the SOGF area and are provided for information only. Those results may or may not imply delivery and/or transmission service related impacts.

4.1. 115 kV Interconnect, 201 MW Output

4.1.1. Voltage Screen

Table 4-1 and Table 4-1A provide voltage screen results for the study area at 201 MW project output with interconnection at 115 kV. These results include the addition of 75 MVAR shunt capacitance at the POI. Without the shunt addition, a converging solution was not attainable.

Table 4-1
Voltage Constraints: System Intact (201 MW @ 115 kV)

BUS/NAME		KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
63007	HAVRE	115	WAPA	0.9992	0.9363	-6.290%	System Intact
63008	HAVRE	161	WAPA	0.9961	0.94	-5.610%	System Intact
63006	HARLEM	161	WAPA	0.9816	0.93	-5.160%	System Intact
63009	MALTA UM	161	WAPA	0.9748	0.9302	-4.460%	System Intact
63011	RICHARDC	161	WAPA	0.9747	0.9398	-3.490%	System Intact
62126	LANDRSFK	230	NWE	0.9664	0.9453	-2.110%	System Intact
7019	BOULDERA	69	NWE	0.9656	0.9497	-1.590%	System Intact
7020	BOULDERB	69	NWE	0.9656	0.9497	-1.590%	System Intact
7023	ELKHORN	69	NWE	0.9647	0.9488	-1.590%	System Intact

Table 4-1A
Voltage Constraints: N-1 Post-Contingent (201 MW @ 115 kV)

BUS/NAME		KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
62027	SHELBY	115	NWE	1.0045	0.8825	-12.200%	GI0814-HV 115
5021	SHELBY	115	NWE	1.004	0.8821	-12.190%	GI0814-HV 115
63007	HAVRE	115	WAPA	0.989	0.8801	-10.890%	GF-BOLE-CRWAPA-230
63006	HARLEM	161	WAPA	0.9734	0.8681	-10.530%	GF-BOLE-CRWAPA-230
63009	MALTA UM	161	WAPA	0.9678	0.8644	-10.340%	GF-BOLE-CRWAPA-230

63008	HAVRE	161	WAPA	0.9871	0.8866	-10.050%	GF-BOLE-CRWAPA-230
63011	RICHARDC	161	WAPA	0.9692	0.8748	-9.440%	GF-BOLE-CRWAPA-230
63015	VERONA	161	WAPA	0.9997	0.9084	-9.130%	GTF-HV 161
63004	FT PECK	161	WAPA	0.9744	0.8881	-8.630%	GF-BOLE-CRWAPA-230
63014	TIBERTAP	115	WAPA	1.0169	0.9316	-8.530%	GI0814-HV 115
63016	GTFWAPA	161	NWE	1.0244	0.9409	-8.350%	GTFWAPA XFMR 161230
62026	SHELBY	230	NWE	1.0142	0.9313	-8.290%	GI0814-HV 115
90113	NATWIND	115	NWE	1.014	0.9449	-6.910%	GI0814-HV 115
5022	BROWNING	115	NWE	1.0144	0.948	-6.640%	GI0814-HV 115
62031	CUTBANK	115	NWE	1.0122	0.9459	-6.630%	GI0814-HV 115
62088	CTBPUMP	115	NWE	1.0129	0.9471	-6.580%	GI0814-HV 115
62023	GT FALLS	161	NWE	0.9716	0.9148	-5.680%	BV-JGS-230

4.1.2. System Operating Limit Screen

Table 4-2 and Table 4-2A provide system operating limit (SOL) thermal constraints for the study area at 201 MW project output with interconnection at 115 kV. Partial Service / Maximum MW Output is provided for each constraint and identifies the curtailment level necessary to mitigate an SOL violation. Partial service was calculated based on 5 MVA margin as required by WAPA.

Table 4-2
Thermal Constraints: System Intact (201 MW @ 115 kV)

Limiting Element	Normal Rating	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
SHELBY-TIBERTAP 115 kV Line 1	80	WAPA	6.8	8.4	89	111.2	41%	167	System Intact
RUDYARD-GI-0814 115 kV Line 1	80	WAPA	9.9	12.4	91.6	114.5	41%	160	System Intact
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.8	113	38%	162	System Intact
HAVRE-RUDYARD 115 kV Line 1	80	WAPA	9	11.3	85.3	106.7	38%	174	System Intact
TIBERTAP-GI-0814 115 kV Line 1	80	WAPA	10.8	13.5	86	107.4	37%	172	System Intact
SHELBY-SHELBY 230-115 kV Tx #1	100	NWE	49.5	49.5	111	111	31%	149	System Intact
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.9	67.2	112.1	20%	140	System Intact

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
TIBERTAP-GI-0814 115 kV Line 1	80/88	WAPA	2.2	2.7 / 2.5	172.1	215.1 / 195.6	85%	96	GI0814-HV 115
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	2.9	3.6 / 3.3	172.1	215.1 / 195.6	84%	95	GI0814-HV 115
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	4.5	5.6 / 5.1	170.2	212.7 / 193.4	82%	95	HV XFMR 115161
SHELBY-TIBERTAP 115 kV Line 1	80/88	WAPA	7.7	9.6 / 8.8	169	211.3 / 192.1	80%	94	GI0814-HV 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	8	10.1 / 9.1	169	211.3 / 192.1	80%	94	GI0814-HV 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7	8.8 / 8.0	167.1	208.9 / 189.9	80%	95	HV XFMR 115161
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	2.3	2.9 / 2.6	111.1	138.9 / 126.2	54%	149	GTF-HV 161
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7	8.8 / 8.0	113.1	141.3 / 128.5	53%	144	GTF-HV 161
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	3.4	4.3 / 3.9	109.4	136.8 / 124.4	53%	151	RB 100161
BOLE-CNRDWAPA 230 kV Line 1	160/176	NWE	97.9	61.2/55.6	203.7	127.3/115.7	53%	139	GI0814-HV 115
BOLE-CNRDWAPA 230 kV Line 1	160 / 176	NWE	96.3	60.2/54.7	201.9	126.2/114.7	53%	142	HV XFMR 115161
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	54.4	54.4/43.5	160	160/128	53%	125	HV XFMR 115161
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	56	56.0 / 44.8	161.3	161.3 / 129.0	52%	122	GI0814-HV 115
SHELBY-CNRDWAPA 230 kV Line 1	160/176	NWE	56.1	35.1 / 31.9	161.3	100.8 / 91.6	52%	201	GI0814-HV 115

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
SHELBY-SHELBY 230-115 kV Tx #1	100/125	NWE	56.1	56.1/44.8	161.3	161.3/129	52%	122	GI0814-HV 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7.6	9.5 / 8.7	111.1	138.9 / 126.3	51%	146	RB 100161
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	3.3	4.2 / 3.8	106.5	133.2 / 121.0	51%	155	GTFWAPA XFMR 161230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.3 / 7.6	108.5	135.6 / 123.2	51%	151	GTFWAPA XFMR 161230
BOLE-GT FALLS 230 kV Line 1	200/220	NWE	102.4	51.2/46.5	203.3	101.7/92.4	50%	201	GI0814-HV 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	26	32.5/30	123.7	154.6/140.6	49%	117	GF-BOLE-CRWAPA-230
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	24.4	30.5/27.7	122	152.5/138.6	49%	121	GF-BOLE-CRWAPA-230
BOLE-CNRDWAPA 230 kV Line 1	160 / 176	NWE	98.2	61.4 / 55.8	194.7	121.7 / 110.6	48%	152	GI0814-HV 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	20.9	26.2 / 23.8	116	145.0 / 131.9	47%	131	SH-CRW 230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	20.9	26.1 / 23.7	115.9	144.9 / 131.7	47%	131	SH XFMR 230115
RUDYARD-GI-0814 115 kV Line 1	80/88	WAPA	7.7	9.6 / 8.7	99.1	123.9 / 112.6	45%	166	HV-VR 161
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	18.5	24.7	106	141.3	44%	118	SH-CRW 230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	18.5	24.6	105.9	141.2	43%	118	SH XFMR 230115
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	19.1	23.9 / 21.7	106.4	133.0 / 120.9	43%	147	SH XFMR 230115
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	19.2	24.0 / 21.8	106.5	133.2 / 121.1	43%	147	SH-CRW 230
TIBERTAP-GI-0814 115 kV Line 1	80 / 88	WAPA	2.4	3.0 / 2.7	89.2	111.5 / 101.3	43%	187	SH-NATW 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	4.7	5.9 / 5.4	91.3	114.1 / 103.7	43%	182	SH-NATW 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	13.8	17.3 / 15.7	98.1	122.6 / 111.4	42%	165	MLRK-CRA-115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	23.5	31.4	107.8	143.8	42%	111	GF-BOLE-CRWAPA-230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	13.6	17.0 / 15.5	97.7	122.2 / 111.1	42%	166	CRA-CRW 115
HAVRE-RUDYARD 115 kV Line 1	80/88	WAPA	9.3	11.6 / 10.5	93.3	116.6 / 106.0	42%	176	HV-VR 161
HAVRE-HAVRE 115-161 kV Tx #1	75/93	WAPA	9.1	12.1 / 9.8	92.8	123.7 / 99.7	42%	189	HV-VR 161
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	25.2	31.5/28.6	108.8	136/123.6	42%	139	FP-RE 161
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	12.3	15.4 / 14.0	95.7	119.6 / 108.8	41%	170	CRW-GF 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	11.4	14.3 / 13.0	94.4	118.0 / 107.3	41%	173	SCB-CRW 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.8	12.2 / 11.1	92.7	115.8 / 105.3	41%	177	MLRK-SCB-115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.5	8.2 / 7.4	89.3	111.7 / 101.5	41%	186	GF-RBW-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.3	11.6 / 10.6	91.9	114.9 / 104.4	41%	179	MLARK-NATW 115
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	5.4	6.8 / 6.2	88	110.0 / 100.0	41%	189	SH-NATW 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89.2	111.4 / 101.3	41%	186	MD-TD-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.4 / 7.7	89.1	111.3 / 101.2	41%	186	RBW-WYP-RAYP-SFA-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.3 / 7.6	89.1	111.4 / 101.3	41%	186	RBW-GFNE-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.3 / 7.6	89.1	111.4 / 101.3	41%	186	GFSE-GFNE-100

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.4 / 7.6	89.1	111.4 / 101.3	41%	186	GF AUTO-230100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.4 / 7.7	89	111.2 / 101.1	41%	186	GR 500230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.4 / 7.7	89	111.2 / 101.1	41%	186	GF-MR-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89.1	111.3 / 101.2	41%	186	GFSS-CFTA-SPKA-CF-EH-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.7	8.4 / 7.7	89	111.2 / 101.1	41%	186	JGA-FRT-FRCP-UTR-UTP-BLD-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	89.2	111.5 / 101.4	41%	186	TD-HT-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	TWN-BRD-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	BRDW-CCK-EUS-TDT-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EHEL-CON-TWN-TST-BRDW-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	BRG-TL-BTCORA-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EHEL-HTB-CL-MTP-BLDR-BRG-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EHEL-HTA-CL-MTPA-MTT-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.4 / 7.7	89	111.2 / 101.1	41%	186	HLT-HVL-EHEL-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	BV AUTO 230100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	HLT-DRUM-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EH-PRECP-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EH-BRGEPM-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	EH-TWN-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	GF-GFES-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.3 / 101.2	41%	186	GFNW-ULMTA-ULMMT-MS-CRG-HOLT-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	GFES-CFTB-SPKB-CF-EH-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	HT-PR-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	PR-BV-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	HT-BV-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	89	111.2 / 101.1	41%	186	MD-KH-MON-BLT-RBW-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	88.9	111.2 / 101.1	41%	187	OV-HS-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	88.9	111.2 / 101.0	41%	187	GF-GFCY-GFSS-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	88.9	111.2 / 101.1	41%	187	GFNW-GFRVW-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.7	88.9	111.2 / 101.0	41%	187	GF-GFCT1-GFCT-GFSS-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.4 / 7.7	88.9	111.2 / 101.1	41%	187	GF-GFRVW-100

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.2	11.5 / 10.5	91.3	114.1 / 103.8	41%	181	CRW XFMR 230115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.9	111.2 / 101.1	41%	187	BV-GR-500
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.8	8.5 / 7.8	88.8	111.1 / 101.0	41%	187	OV-GR-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.9	111.1 / 101.0	41%	187	GF-STAP-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.9	111.1 / 101.0	41%	187	GF-SO-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.8	111.0 / 100.9	41%	187	CRA XFMR 11569
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.8	111.0 / 100.9	41%	187	EH-TR 230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10.1	12.6 / 11.4	91.9	114.9 / 104.5	41%	179	NATW-SCB
RUDYARD-GI-0814 115 kV Line 1	80/88	WAPA	10.1	12.6 / 11.4	91.9	114.9 / 104.5	41%	179	GF-LF-OV-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.5	8.2 / 7.4	88.3	110.4 / 100.4	41%	188	MLARK-NATW 115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	6.9	8.6 / 7.8	88.7	110.9 / 100.8	41%	187	GF XFMR 115100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10	12.5 / 11.4	91.8	114.8 / 104.3	41%	179	GF XFMR 115100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.7	114.6 / 104.2	41%	180	GF-MR-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10.1	12.6 / 11.4	91.8	114.7 / 104.3	41%	179	CRA XFMR 11569
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10	12.5 / 11.4	91.7	114.6 / 104.2	41%	180	OV-GR-230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.7	12.2 / 11.1	91.4	114.3 / 103.9	41%	180	RBW-GFNE-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.5	11.8 / 10.8	91.2	114.0 / 103.6	41%	181	GF-RBW-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.7	12.2 / 11.1	91.4	114.3 / 103.9	41%	180	GFSE-GFNE-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.8	12.3 / 11.2	91.5	114.3 / 103.9	41%	180	GFNW-ULMTA-ULMMT-MS-CRG-HOLT-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	TWN-BRD-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	GR 500230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	BRDW-CCK-EUS-TDT-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	EHEL-CON-TWN-TST-BRDW-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	BRG-TL-BTCORA-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	EHEL-HTB-CL-MTP-BLDR-BRG-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	EHEL-HTA-CL-MTPA-MTT-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	HLT-HVL-EHEL-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	EH 230100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	OV-HS-230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	EH-PRECP-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	EH-BRGEPM-100

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	EH-TWN-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.6 / 104.1	41%	180	GF-GFCY-GFSS-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	GFNW-GFRVW-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.6 / 104.1	41%	180	GF-GFCT1-GFCT-GFSS-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	GF-GFRVW-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	GLY-BLD-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.6	114.5 / 104.1	41%	180	JGA-FRT-FRCP-UTR-UTP-BLD-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.4 / 104.0	41%	180	HT-PR-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	PR-BV-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.4 / 104.0	41%	180	HT-BV-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	HT-JGT-JGA-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.8	12.3 / 11.2	91.4	114.3 / 103.9	41%	180	RBW-WYP-RAYP-SFA-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.8	12.3 / 11.2	91.4	114.3 / 103.9	41%	180	GFSS-CFTA-SPKA-CF-EH-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.8	12.2 / 11.1	91.4	114.2 / 103.8	41%	180	GF AUTO-230100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10	12.5 / 11.4	91.6	114.5 / 104.1	41%	180	EH-TR 230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10.4	13.0 / 11.9	92	114.9 / 104.5	41%	179	GF-EH 230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.3 / 11.2	91.5	114.4 / 104.0	41%	180	HLT-DRUM-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10	12.5 / 11.3	91.6	114.5 / 104.1	41%	180	GF-STAP-230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.3 / 11.2	91.5	114.4 / 104.0	41%	180	GF-GFES-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10	12.4 / 11.3	91.6	114.5 / 104.1	41%	180	GF-SO-230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.3 / 11.2	91.5	114.4 / 104.0	41%	180	GFES-CFTB-SPKB-CF-EH-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.5	114.4 / 104.0	41%	180	MD-KH-MON-BLT-RBW-100
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7	8.8 / 8.0	88.5	110.7 / 100.6	41%	187	NATW-SCB
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10.2	12.8 / 11.6	91.7	114.7 / 104.3	41%	180	STAP-JG-JGS-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7.1	8.9 / 8.1	88.5	110.6 / 100.6	40%	187	STAP-JG-JGS-230
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7.1	8.9 / 8.1	88.5	110.6 / 100.6	40%	187	GF-EH 230
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.2	91.3	114.1 / 103.8	40%	181	MD-TD-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	9.9	12.4 / 11.3	91.2	114.1 / 103.7	40%	181	TD-HT-100
RUDYARD-GI-0814 115 kV Line 1	80 / 88	WAPA	10.4	12.9 / 11.8	91.6	114.5 / 104.1	40%	180	BV-JGS-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	22.8	30.4	103.8	138.4	40%	117	FP-RE 161
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7.8	9.7 / 8.8	88.8	110.9 / 100.9	40%	187	CRW XFMR 230115
SHELBY-TIBERTAP 115 kV Line 1	80 / 88	WAPA	7.4	9.2 / 8.4	88.3	110.3 / 100.3	40%	188	BV-JGS-230

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	23.2	29.0 / 26.3	102.8	128.5 / 116.8	40%	151	FP-RE 161
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	11.7	15.7	90.6	120.8	39%	149	MLRK-CRA-115
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	12.4	15.5 / 14.1	91.2	114.0 / 103.6	39%	180	MLRK-CRA-115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	11.5	15.4	90.3	120.4	39%	149	CRA-CRW 115
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	12.2	15.2 / 13.8	90.9	113.6 / 103.3	39%	181	CRA-CRW 115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	10.5	13.9	88.5	117.9	39%	153	CRW-GF 115
HAVRE-RUDYARD 115 kV Line 1	80 / 88	WAPA	11.1	13.9 / 12.6	89	111.3 / 101.2	39%	186	CRW-GF 115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	9.7	12.9	87.3	116.4	39%	156	SCB-CRW 115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.3	11.1	85.7	114.3	39%	160	MLRK-SCB-115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	7.9	10.6	85	113.4	38%	162	MLARK-NATW 115
HAVRE-HAVRE 115-161 kV Tx #1	75/93	WAPA	8.1	10.8 / 8.7	84.7	112.9 / 91.0	38%	201	GF-LF-OV-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	7.9	10.5	84.5	112.7	38%	163	CRW XFMR 230115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	85.1	113.4	38%	161	NATW-SCB
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	85	113.3	38%	162	GF XFMR 115100
HAVRE-RUDYARD 115 kV Line 1	80/88	WAPA	8.7	10.9 / 9.9	85.2	106.5 / 96.9	38%	195	GF-LF-OV-230
SHELBY-TIBERTAP 115 kV Line 1	80/88	WAPA	5.6	7.0 / 6.4	82	102.5 / 93.2	38%	201	HV-VR 161
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8	10.7	84.4	112.6	38%	163	GF-RBW-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.8	113.1	38%	162	GR 500230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.8	113	38%	162	GR-TT-500
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.8	113.1	38%	162	GF-GFRVW-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.8	113	38%	162	GLY-BLD-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.8	113	38%	162	JGA-STRWT-STRP-GLY-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	84.9	113.2	38%	162	CRA XFMR 11569
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	TWN-BRD-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	BRDW-CCK-EUS-TDT-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	EHEL-CON-TWN-TST-BRDW-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	BRG-TL-BTCORA-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	EHEL-HTB-CL-MTP-BLDR-BRG-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	EHEL-HTA-CL-MTPA-MTT-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	HLT-HVL-EHEL-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	BV AUTO 230100

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.8	113	38%	162	OV-HS-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	112.9	38%	162	HLT-DRUM-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	EH-PRECP-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	EH-BRGEPM-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	EH-TWN-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.3	11	84.6	112.8	38%	163	RBW-GFNE-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.8	113.1	38%	162	GF-GFCY-GFSS-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.3	11	84.6	112.8	38%	163	GFSE-GFNE-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.8	113	38%	162	GFNW-GFRVW-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.8	113.1	38%	162	GF-GFCT1-GFCT-GFSS-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.8	113.1	38%	162	GF-MR-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.7	113	38%	162	JGA-FRT-FRCP-UTR-UTP-BLD-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.7	113	38%	162	PR-BV-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	113	38%	162	E HELENA XFMR 1 11069
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	113	38%	162	BV AUTO 500230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	113	38%	162	CS-BV-500
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	84.8	113.1	38%	162	OV-GR-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.3	11.1	84.5	112.7	38%	163	GF AUTO-230100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	112.9	38%	162	HT-PR-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	112.9	38%	162	HT-BV-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.3	84.7	112.9	38%	162	MD-KH-MON-BLT-RBW-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.6	112.8	38%	162	RBW-WYP-RAYP-SFA-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.6	112.9	38%	162	GF-GFES-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.6	112.8	38%	162	GFNW-ULMTA-ULMMT-MS-CRG-HOLT-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.2	84.6	112.8	38%	162	GFSS-CFTA-SPKA-CF-EH-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.4	11.3	84.6	112.9	38%	162	GFES-CFTB-SPKB-CF-EH-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.4	84.6	112.8	38%	162	GF-STAP-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.5	11.4	84.6	112.8	38%	162	GF-SO-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	84.6	112.8	38%	162	EH-TR 230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	84.6	112.8	38%	162	BV-GR-500
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	9	12	84.7	113	38%	162	GF-EH 230

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.6	11.4	84.3	112.5	38%	163	MD-TD-100
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.8	11.8	84.3	112.4	38%	163	STAP-JG-JGS-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	8.7	11.6	84.2	112.3	38%	163	TD-HT-100
TIBERTAP-GI-0814 115 kV Line 1	80/88	WAPA	10.3	12.9 / 11.7	85.7	107.1 / 97.4	38%	194	GF-LF-OV-230
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	6.5	8.7	81.6	108.8	37%	170	SH-NATW 115
HAVRE-HAVRE 115-161 kV Tx #1	75	WAPA	9.1	12.1	84.4	111.1	37%	162	BV-JGS-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	43.8	73	115.3	192.2	36%	31	VR-GTFWAPA 161
BOLE-CNRDWAPA 230 kV Line 1	160 / 176	NWE	112.1	70.1/63.6	182.9	114.3/103	35%	167	CRW-GF 115
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	55.4	55.4/44	125.6	125.6/100.5	35%	185	GTF-HV 161
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	55.2	55.2/44	124.9	124.9/100	35%	187	VR-GTFWAPA 161
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	55.2	55.2/44	124.8	124.8/99.84	35%	187	RB 100161
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	43.9	73.2	112.7	187.9	34%	32	GTFWAPA XFMR 161230
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	83	83/66.4	150.1	150.1/120	33%	111	MLRK-CRA-115
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	81.6	81.6/65.3	148.6	148.6/119	33%	115	CRA-CRW 115
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	62.2	62.2/49.8	128.9	128.9/103	33%	174	SCB-CRW 115
SHELBY-SHELBY 230-115 kV Tx #1	100/125	NWE	48.4	48.4/38.7	109.2	109.2/87.36	30%	201	GF-LF-OV-230
SHELBY-SHELBY 230-115 kV Tx #1	100 / 125	NWE	69.1	69.1/55.3	128.9	128.9/103	30%	171	CRW XFMR 230115
SHELBY-SHELBY 230-115 kV Tx #1	100/125	NWE	56.1	56.1/44.8	106.7	106.7/85.4	25%	201	HV-VR 161
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	32	53.3	80.6	134.3	24%	95	SH-CRW 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	32	53.3	80.5	134.2	24%	95	SH XFMR 230115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	33	54.9	80	133.3	23%	94	GF-BOLE-CRWAPA-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	29	48.3	71.2	118.7	21%	124	MLRK-CRA-115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	28.8	48.1	71	118.3	21%	125	CRA-CRW 115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	28.5	47.5	70.2	117.1	21%	128	CRW-GF 115

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	23.7	39.5	65.3	108.8	21%	151	SH-NATW 115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27.7	46.2	68.9	114.9	20%	133	SCB-CRW 115
VAL-WILL-MLARK 115 kV Line 1	133	NWE	110.2	82.9	151.3	113.8	20%	87	SH-CRW 230
CONRAD-VAL-WILL 115 kV Line 1	133	NWE	109.3	82.2	150.3	113	20%	92	SH XFMR 230115
CONRAD-VAL-WILL 115 kV Line 1	133	NWE	109.3	82.2	150.3	113	20%	92	SH-CRW 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.9	113.1	20%	138	MLRK-SCB-115
CNRDWAPA-CONRAD 115 kV Line 1	134	NWE	106.1	79.5	147.1	110.2	20%	112	SH-CRW 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	28	46.7	68.9	114.9	20%	133	STAP-JG-JGS-230
VAL-WILL-MLARK 115 kV Line 1	133	NWE	110.3	82.9	151.2	113.7	20%	87	SH XFMR 230115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.6	44.3	67.4	112.4	20%	140	MLARK-NATW 115
CNRDWAPA-CONRAD 115 kV Line 1	134	NWE	106.2	79.5	147	110.1	20%	112	SH XFMR 230115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	29.9	49.8	70.4	117.4	20%	125	GF-EH 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.1	43.5	66.6	110.9	20%	143	CRW XFMR 230115
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	45	67.4	112.4	20%	139	NATW-SCB
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	44.9	67.4	112.3	20%	139	GR 500230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	45	67.4	112.3	20%	139	GF XFMR 115100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27.1	45.1	67.5	112.4	20%	139	EH-TR 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27.6	46.1	68	113.4	20%	136	OV-GR-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27.1	45.2	67.5	112.5	20%	139	OV-HS-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.9	67.3	112.2	20%	140	HT-JGT-JGA-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.9	67.2	112	20%	140	E HELENA XFMR 1 11069
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	BV AUTO 500230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	BV AUTO 230100
GT FALLS-RAINBOW 161-100 kV Tx	60	NWE	26.9	44.8	67.2	112	20%	140	GR-TT-500

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
#1									
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.4	44	66.7	111.2	20%	143	RBW-GFNE-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	GF-GFCY-GFSS-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.4	44	66.7	111.2	20%	143	GFSE-GFNE-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	GF-GFCT1-GFCT-GFSS-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112.1	20%	140	GF-SO-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	GLY-BLD-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.2	112	20%	140	JGA-STRWT-STRP-GLY-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67.1	111.8	20%	141	TWN-BRD-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67.1	111.8	20%	141	BRDW-CCK-EUS-TDT-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.6	67.1	111.8	20%	141	EHEL-CON-TWN-TST-BRDW-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.6	67	111.7	20%	141	BRG-TL-BTCORA-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.5	67	111.7	20%	141	EHEL-HTB-CL-MTP-BLDR-BRG-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.6	67	111.7	20%	141	EHEL-HTA-CL-MTPA-MTT-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.5	67	111.7	20%	141	HLT-HVL-EHEL-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	45	67.3	112.2	20%	140	CRA XFMR 11569
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	45	67.3	112.2	20%	140	EH 230100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67.1	111.8	20%	141	BV-GR-500
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.3	43.8	66.6	111	20%	143	HLT-DRUM-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.6	67	111.7	20%	141	EH-PRECP-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.7	44.5	67	111.7	20%	141	EH-BRGEPM-100
GT FALLS-RAINBOW 161-100 kV Tx	60	NWE	26.8	44.6	67.1	111.8	20%	141	EH-TWN-100

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
#1									
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	25.7	42.8	66	110	20%	146	GF-RBW-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	45	67.3	112.1	20%	140	GFNW-GFRVW-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27	44.9	67.3	112.2	20%	140	GF-GFRVW-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67.1	111.8	20%	141	JGA-FRT-FRCP-UTR-UTP-BLD-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	27.5	45.8	67.7	112.9	20%	138	GF-MR-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67	111.7	20%	141	HT-PR-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	67	111.7	20%	141	HT-BV-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.9	44.8	67.1	111.9	20%	141	PR-BV-100
BROADVU-JGWIND 230 kV Line 1	478	NWE	446.3	93.4	486.5	101.8	20%	134	GF-LF-OV-230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.8	44.7	66.9	111.5	20%	141	MD-KH-MON-BLT-RBW-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.2	43.6	66.3	110.5	20%	144	GF-GFES-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.2	43.7	66.3	110.5	20%	144	GFES-CFTB-SPKB-CF-EH-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.1	43.5	66.1	110.2	20%	145	GFNW-ULMTA-ULMMT-MS-CRG-HOLT-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.1	43.4	66.1	110.2	20%	145	GFSS-CFTA-SPKA-CF-EH-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.4	43.9	66.3	110.6	20%	144	RBW-WYP-RAYP-SFA-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.1	43.6	65.7	109.4	20%	147	MD-TD-100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	25.7	42.8	65.2	108.6	20%	149	GF AUTO-230100
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	26.1	43.6	65.6	109.4	20%	147	TD-HT-10
CNRDWAPA-CNRDWAPA 230-115 kV Tx #1	100/125	NWE	78.3	78.3	116.7	116.7/93.4	19%	201	SH XFMR 230115

4.1.3. Conclusions for 115 kV Interconnect, 201 MW Output

A converging solution for loss of the Shelby 2 – Tiber Tap – POI 115 kV line was not attainable without reducing the GI-0814 plant output to 140 MW.

Significant system intact and N-1 post-contingent system performance criteria violations exist at 201 MW project output with interconnection at 115 kV and the addition of 75 MVAR shunt capacitance at the POI. The 115 kV system cannot support interconnection of 201 MW without conversion of the local BES to 230 kV.

4.2. 115 kV Interconnect, 70 MW Output

4.2.1. Voltage Screen

Table 4-3 and Table 4-3A provide voltage screen results for the study area at 70 MW project output with interconnection at 115 kV.

Table 4-3
Voltage Constraints: System Intact (70 MW @ 115 kV)

BUS/NAME	KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
NONE						

Table 4-3A
Voltage Constraints: N-1 Post-Contingent (70 MW @ 115 kV)

BUS/NAME		KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
63006	HARLEM	161	WAPA	0.9795	0.947	-3.250%	SH-GI0814 115
63009	MALTA UM	161	WAPA	0.9731	0.945	-2.810%	SH-GI0814 115

4.2.2. System Operating Limit Screen

Table 4-4 and Table 4-4A provide system operating limit (SOL) thermal constraints for the study area at 70 MW project output with interconnection at 115 kV. Partial Service / Maximum MW Output is provided for each constraint and identifies the curtailment level necessary to mitigate an SOL violation. Partial service was calculated based on 5 MVA margin as required by WAPA.

Table 4-4
Thermal Constraints: System Intact (70 MW @ 115 kV)

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
NONE									

Table 4-4A
Thermal Constraints: N-1 Post-Contingent (70 MW @ 115 kV)

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
GT FALLS- RAINBOW 161-100 Tx 1	60	NWE	44.1	73.5	70.4	117.4	37.57%	29	VR-GTFWAPA 161
GT FALLS- RAINBOW 161-100 Tx 1	60	NWE	43.9	73.1	69.6	116	36.71%	30	GTFWAPA XFMR 161230

4.2.3. Conclusions for 115 kV Interconnect, 70 MW Output

Voltage constraints at 70 MW project output with interconnection at 115 kV do not violate system performance criteria. However, shunt MVAR support may be necessary at the POI and would be determined with a System Impact Study (SIS).

Thermal constraints at 70 MW project output with interconnection at 115 kV do not violate system performance criteria for the study area. However, mitigation of overload of NWE's Great Falls-Rainbow 161/100 kV transformer is likely for delivery purposes (provided as information only).

4.3. 230 kV Interconnect, 201 MW Output

4.3.1. Voltage Screen

Table 4-5 and Table 4-5A provide voltage screen results for the study area at 201 MW project output with interconnection at 230 kV.

Table 4-5
Voltage Constraints: System Intact (201 MW @ 230 kV)

BUS/NAME	KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
NONE						

Table 4-5A
Voltage Constraints: N-1 Post-Contingent (201 MW @ 230 kV)

BUS/NAME	KV	Owner	Pre Project	Post Project	Delta Volt %	Contingency
NONE						

4.3.2. System Operating Limit Screen

Table 4-6 and Table 4-6A provide system operating limit (SOL) thermal constraints for the study area at 201 MW project output with interconnection at 230 kV. Partial Service / Maximum MW Output is provided for each constraint and identifies the curtailment level necessary to mitigate an SOL violation. Partial service was calculated based on 5 MVA margin as required by WAPA.

It should be noted that the 230 kV conversion assumed for this project was based on a minimal normal and emergency rating of 160 and 176 MVA respectively, with 954 ACSR wood pole H-frame construction. This assumption, closely matches the optimal surge impedance loading (SIL) of a 230 kV circuit. Therefore, thermal SOL screening was based on 160 MVA for normal operation and 176 MVA for emergency operation. However, if increased capacity of the 230 kV converted system is needed to mitigate SOL violations, shunt MVAR compensation may be relied upon to increase 230 kV capabilities in excess of 300 MVA and would be determined in a SIS.

Table 4-6
Thermal Constraints: System Intact (201 MW @ 230 kV)

Limiting Element	Rating N/E	Owner	Pre Project		Post Project		DF	Partial Service or MAX MW Output	Contingency
			MVA	%	MVA	%			
NONE									

Table 4-6A
Thermal Constraints: N-1 Post-Contingent (201 MW @ 230 kV)

Limiting Element	Rating N/E	Owner	Pre Project MVA	Pre Project %	Post Project MVA	Post Project %	DF	Partial Service or MAX MW Output	Contingency
TIBERTAP-GI-0814 230 kV Line 1	160 / 176	WAPA	0.7	0.4 / 0.4	197.2	123.3 / 112.1	97.76%	174	GI0814-HV 230
RUDYARD-GI-0814 230 kV Line 1	160 / 176	WAPA	0.9	0.6 / 0.5	197.2	123.3 / 112.1	97.66%	174	SH-GI0814 230
RUDYARD-HAVRE4 230 kV Line 1	160 / 176	WAPA	1.7	1.0 / 0.9	195.6	122.3 / 111.1	96.47%	175	SH-GI0814 230
SHELBY-TIBERTAP 230 kV Line 1	160 / 176	WAPA	11.4	7.1 / 6.5	201.5	126.0 / 114.5	94.58%	169	GI0814-HV 230
SHELBY-CNRDWAPA 230 kV Line 1	160 / 176	WAPA	56.5	35.3 / 32.1	221.6	138.5 / 125.9	82.14%	139	GI0814-HV 230
VERONA-HAVRE4 230 kV Line 1	160 / 176	WAPA	30	18.7 / 17.0	176.7	110.4 / 100.4	72.99%	193	SH-GI0814 230
RUDYARD-HAVRE4 230 kV Line 1	160/176	WAPA	42.7	26.7/24.26	187	116.9/106	71.79%	179	SH-CRW 230
RUDYARD-GI-0814 230 kV Line 1	160/176	WAPA	44.5	27.8/25.28	188.6	117.9/107	71.69%	176	SH-CRW 230
RUDYARD-HAVRE4 230 kV Line 1	160/176	WAPA	60.4	37.7/34.32	189.4	118.4/108	64.18%	172	GF-BOLE-CRWAPA-230
RUDYARD-GI-0814 230 kV Line 1	160/176	WAPA	62.3	38.9/35.4	191	119.4/109	64.03%	170	GF-BOLE-CRWAPA-230
BOLE-CNRDWAPA 230 kV Line 1	160 / 176	WAPA	98.1	61.3 / 55.7	226.7	141.7 / 128.8	63.98%	114	GI0814-HV 230
BOLE-GT FALLS 230 kV Line 1	200 / 220	WAPA	103.3	51.7 / 47.0	231.6	115.8 / 105.3	63.83%	175	GI0814-HV 230
SHELBY-CNRDWAPA 230 kV Line 1	160/176	WAPA	61.4	38.4/34.89	187.2	117/106	62.59%	175	HV-VR 230
SHELBY-CNRDWAPA 230 kV Line 1	160 / 176	WAPA	61.6	38.5 / 35.0	186.5	116.6 / 106.0	62.14%	176	VR-GT FALLS 230
BOLE-CNRDWAPA 230 kV Line 1	160/176	WAPA	103	64.4/58.52	204.7	127.9/116	50.60%	134	HV-VR 230
VERONA-HAVRE4 230 kV Line 1	160/176	WAPA	79.2	49.5/45	178.2	111.4/101	49.25%	186	GF-BOLE-CRWAPA-230
BOLE-CNRDWAPA 230 kV Line 1	160 / 176	WAPA	103.1	64.5 / 58.6	201.9	126.2 / 114.7	49.15%	138	VR-GT FALLS 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	37.3	62.2	84.4	140.6	23.43%	76	HV-VR 230
GT FALLS-RAINBOW 161/100 Tx #1	60	NWE	37.1	61.9	83.1	138.5	22.89%	78	VR-GT FALLS 230
GT FALLS-RAINBOW 161-100 kV Tx #1	60	NWE	17.5	29.2	60.7	101.1	21.49%	174	SH-GI0814 230

4.3.3. Conclusions for 230 kV Interconnect, 201 MW Output

Voltage constraints at 201 MW project output with interconnection at 230 kV do not violate system performance criteria. However, shunt MVAR support may be necessary at the POI and would be determined in a System Impact Study (SIS).

Some thermal constraints at 201 MW project output with interconnection at 230 kV do violate system performance criteria for the study area during local N-1 outages with assumed 230 kV normal and emergency SOLs of 160 MVA and 176 MVA respectively. However, mitigation is proposed with a 230 kV conversion design that meets or exceeds a 200 MVA normal SOL. In addition, overload of NWE's Great Falls-Rainbow 161/100 kV transformer is likely for delivery purposes (provided as information only).

As an alternate 230 kV conversion design, it is concluded that minimal 230 kV conversion of the BES from the POI to Shelby 2 would meet criteria with a WECC approved remedial action scheme (RAS) that curtails the plant output from 201 MW to 70 MW for a 230 kV transmission outage between the POI and Shelby 2.

5. Short Circuit Analysis

Short circuit analysis of available fault currents were performed, using CAPE, for the immediate project area, specifically Western's Havre-Rudyard-Shelby2 115 kV system and NWE's associated underlying 69 kV system. No short circuit analysis was performed for 230 kV interconnection since new equipment would be required for 230 kV conversion and the interrupting duties would be specified accordingly. Single line to ground (SLG) and three phase (3PH) fault currents were simulated at the 115kV Project collector bus, 115 kV Havre bus and 115 kV Rudyard bus. Fault currents for these simulations and the most limiting breaker interrupting ratings are summarized in Table 5-1.

Table 5-1
Pre and Post-Project Fault Duty vs Breaker Capability
201 MW Interconnection at 115 kV

BUS			Available SLG Fault Current				Available 3PH Fault Current				Interrupting Capability Of Least Capable Breaker (kA)
Number	Name	kV	G814 Project Off kA	G814 Project On kA	Current Change kA	% Interrupting Capability with Project On	G814 Project Off kA	G814 Project On kA	Current Change kA	% of Interrupting Capability with Project On	
19	GI_814_TAP	115	1.33	4.73	3.40	TBD	2.04	5.11	3.07	TBD	TBD
11	North Joplin	69	0.50	0.53	0.02	5%	0.66	0.72	0.06	7%	10.0
18	Wildhorse	69	0.34	0.35	0.01	1%	0.49	0.52	0.03	1%	40.0
10	North Havre	69	0.40	0.41	0.01	2%	0.48	0.51	0.03	3%	20.0
3	Goldstone	69	0.64	0.68	0.04	3%	0.80	0.89	0.09	4%	20.0
1	Gildford	69	0.53	0.55	0.03	6%	0.69	0.75	0.06	8%	10.0
15	Tiber	115	1.01	1.50	0.49	4%	1.58	2.22	0.64	6%	40.0
62026	Shelby 2	115	3.93	4.45	0.52	22%	3.74	4.24	0.50	21%	20.0
17	Tiber(old)	115	1.04	1.55	0.52	4%	1.61	2.29	0.67	6%	40.0
12	Rudyard	69	1.60	1.86	0.26	6%	1.40	1.69	0.29	5%	31.5
6	Havre	115	2.84	3.29	0.45	16%	2.63	3.17	0.54	16%	20.0
7	Havre	161	2.38	2.62	0.25	16%	2.28	2.59	0.31	16%	16.0

A comparison of the fault currents to the breaker capabilities at these local substations indicates there is adequate interrupting capability following the addition of the new generation at 201 MW. This will also hold true for the 70 MW output level as the impact would be less.

6. Conceptual Cost Estimates

Table 6-1 provides conceptual cost estimates for 70 MW of project output with interconnection at 115 kV. Table 6-2 and Table 6-2A provide conceptual cost estimates for 201 MW of project output with interconnection at 230 kV. Table 6-2 assumes total conversion of the local 115 kV BES to 230 kV operation. Table 6-2A assumes minimal conversion of the 115 kV BES from POI to Shelby 2 and installation of a WECC approved remedial action scheme (RAS) to curtail the plant output from 201 MW to 70 MW for an outage of the transmission between the POI and Shelby 2. WAPA does not assume responsibility for the accuracy of these non-binding costs beyond conceptual planning purposes. More accurate cost estimates and construction schedules would be determined in a Facilities Study.

Table 6-1
Conceptual Costing
115kV Interconnect, 70 MW Output

Project Output	***Facility / Addition***	***Installed Cost (per $1,000 (USD) unit)***
70 MW	**New Switchyard at POI**	
	3 Terminal 115 kV Ring Bus	$2,800
	Metering & Instrumentation	$100
		$2,900

Table 6-2
Conceptual Costing
230kV Interconnect, 201 MW Output

Project Output	***Facility / Addition***	***Installed Cost (per $1,000 (USD) unit)***
201 MW w/o RAS	**New Switchyard at POI**	
	3 Terminal 230 kV Ring Bus	$3,400
	Metering & Instrumentation	$100
	230kV H-Frame Transmission (954 ACSR)	
	50 miles, POI to Shelby 2 Substation	$13,830
	Tiber Tap 230 kV Conversion	
	3-way 230 kV Line Disconnect	$100
	Single 230 kV Terminal	$1,120
	230/115 kV Auto-Transformer, 10 MVA	$800
	Single 115 kV Terminal	$800
	Shelby 2 Substation Upgrade	
	Terminal Addition to 230 kV Bus	$1,120
	230kV H-Frame Transmission (954 ACSR)	
	47 miles, POI to Havre Substation	$13,000
	Rudyard Tap 230 kV Conversion	
	3-way 230 kV Line Disconnect	$100
	Single 230 kV Terminal	$1,120

	230/115 Auto-Transformer, 33 MVA	$1,100
	Havre 230 kV Conversion	
	3 Terminal 230 kV Ring Bus	$3,400
	230/161 kV Auto-Transformer, 200 MVA	$2,700
	Single 161 kV Terminal	$950
	Metering & Instrumentation	$100
	230kV H-Frame Transmission (954 ACSR)	
	103 miles, Havre-Verona-Great Falls	$28,500
	Verona 230 kV Conversion	
	3 Terminal 230 kV Ring Bus	$3,400
	230/69 kV Auto-Transformer, 33 MVA	$1,350
	Metering & Instrumentation	$100
	Great Falls 230 kV Terminal	
	Remove 230/161 kV, 100 MVA Transformer	$100
	Metering & Instrumentation	$100
		$77,290

Table 6-2A
Conceptual Costing
230kV Interconnect, 201 MW Output

Project Output	***Facility / Addition***	***Installed Cost (per $1,000 (USD) unit)***
201 MW w/ RAS	**New Switchyard at POI**	
	3 Terminal 230 kV Ring Bus	$3,400
	230/161 kV Auto-Transformer, 200 MVA	$2,700
	Single 161 kV Terminal	$950
	Metering & Instrumentation	$100
	Remedial Action Scheme (RAS)	$200
	230kV H-Frame Transmission (954 ACSR)	
	50 miles, POI to Shelby 2 Substation	$13,830
	Tiber Tap 230 kV Conversion	
	3-way 230 kV Line Disconnect	$100
	Single 230 kV Terminal	$1,120
	230/115 kV Auto-Transformer, 10 MVA	$800
	Single 115 kV Terminal	$800
	Shelby 2 Substation Upgrade	
	Terminal Addition to 230 kV Bus	$1,120
		$25,120

Appendix A: Model Documentation

Provided Upon Request

Appendix B: List of Modeled Generation

Provided Upon Request

Appendix C: Detailed Results

Provided Upon Request

Appendix D: Unsolved Contingencies

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Appendix E: Contingencies

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APPENDIX F: Powerflow Diagrams

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